THE FORMATION OF SOME CONE CHAINS IN CHRYSE PLANITIA ON MARS. L. Czechowski[1], N. Zalewska[2], A. Zambrowska[2], M. Ciążela[3], P. Witek[4], J. Kotlarz[5], [1]University of Warsaw, Faculty of Physics, Institute of Geophysics, ul. Pasteura 5, 02-093 Warszawa, Poland, lczech@op.pl, tel. +48 22 55 32 003, [2]Space Research Center PAS, ul. Bartycka 18 A, 00-716 Warszawa, Poland, [3]Space Research Center PAS, ul. Bartycka 18 A, 00-716 Warszawa, Poland (presently Institute of Geological Sciences, PAS. ul. Twarda 51/55, 00-818 Warszawa, Poland). [4]Copernicus Science Centre, ul. Wybrzeże Kościuszkowskie 20, 00-390 Warszawa, Poland, [5]Łukasiewicz Research Network - Institute of Aviation, Al. Krakowska 110/114, 02-256 Warszawa, Poland.

Introduction: Small cones are common on Mars. Many cones form subparallel chains several kilometers in length. Their origin is discussed in many papers, however, the mechanism of their formation is not explained, nor the reason for their arrangement in subparallel chains. According to [1] cones in Acidalia Planitia (Pl.) may be: cinder cones, rootless cones, tuff cones, tuff rings, pingos, mud volcanoes and hot spring deposits. Recent conclusions of [2] (concerning Chryse Planitia) are not dramatically different.

In the present paper, we deal with a small region in Chryse Pl. (centered on ~38°13′ N and ~319°25’ E) where several chains of cones are observed – Figs. 1 and 2. The main subject of our research is a hill ~15x11 km. The hill is separated from other hills by the valleys (with the chains labeled by 7 and 8).

We try: (1) to explain the processes responsible for the formation of cones, (2) to investigate energy required for cones formation, and (3) to explain why the cones form subparallel chains.

Description of the region: The region is at the boundary of smooth plain (AHcs) and complex unit (AHcc). The small region labeled by HNck is the “older knobby material” – [3], where AH stands for Amazonian-Hesperian, and HN - Hesperian-Noachian. The region is covered by lacustrine deposits. Note also the lava flows (in HNck).

Fig. 1 shows irregular hills stretching in the N-S direction at the boundary of AHcs and AHcc. Their height is ~25 m (cones give additional ~10-20 m).

Formation of cones: On Mars, chains of small cones occupy vast areas. On other terrestrial planets such chains are not as that common. Therefore, we try to explain the existence of the chains by specific conditions on Mars. In Mars history there was a period when vast hydrosphere became unstable due to the decrease of atmospheric pressure in the late Hesperian - [4]. Therefore, we focus on the hypothesis connecting the formation of cones with the loss of water from the regolith due its instability. Similar ideas were considered for other regions, e.g. [1], [2], [5].

Mechanism of cones formation: We consider 3 mechanisms of cone formation: (i) a grains’ ejection, (ii) from mud or fluidized sand and (iii) explosive formation. The (iii) and (ii) are possible when an additional heat source (e.g., hot magma) has increased the temperature. Of course, the cones may be formed by several processes.

Fig. 1 Topography of the considered region. Topography is based on MOLA/HRSC Blended Digital Elevation Model 200 m on THEMIS Day IR layer.

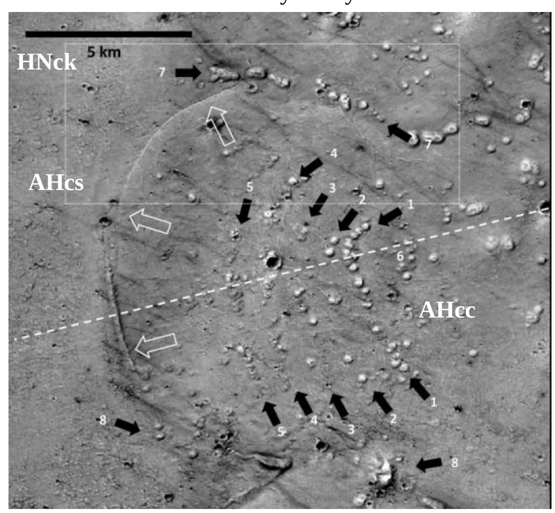

Fig. 2 The region considered in the paper (see also Fig. 1). The chains of cones are indicated by black arrows and labeled by 1, 2, 3, 4, 5. According to our hypotheses, some of these chains were formed along the outcrops of sediments with high content of volatiles. The chains 7 and 8 may be rootless cones formed at the bottom of the valleys. NASA, P22_009485_2187_XN_ 38N040W.

Heat balance; Let consider water trapped in the aquifer. Water’s stability depends on pressure, temperature and composition. If a fissure is formed in the covering layer extending from the surface to the aquifer, then the pressure in the aquifer will drop and the water could be unstable and will boil. The steam will flow through the fissure into the atmosphere, entraining grains of sand and dust. Assuming that only heat of melting was used for vaporization, we got that ratio of vapor to ice is:

$$m_{vap}/m_{ice} = C_m/C_b = 0.148,$$

where C_b, C_m , m_{vap}, m_{ice} are heat of vaporization, heat of melting, mass of steam, mass of ice, respectively. Note that only ~13% of liquid water will be vaporized, while 87% will freeze. If the outgassing effect is to be regolith without water, then we must also take into account other heat sources, e.g., magma intrusions.

Interaction of magma intrusion and aquifer; We present the calculation of the interaction of a magma intrusion and an aquifer using 3D, time dependent model developed by [6]. The temperature is given by the equation:

$$c\,\rho\,\partial T/\partial t = \mathrm{div}(k\ \mathrm{grad}\ T) + Q, \qquad (2)$$

where t [s] is the time, T [K] is the temperature, c [J kg^{-1} K^{-1}] is the specific heat, ρ [kg m^{-3}] is the density, k [W m^{-1} K^{-1}] is thermal conductivity and Q [W m^{-3}] is the rate of heat generation.

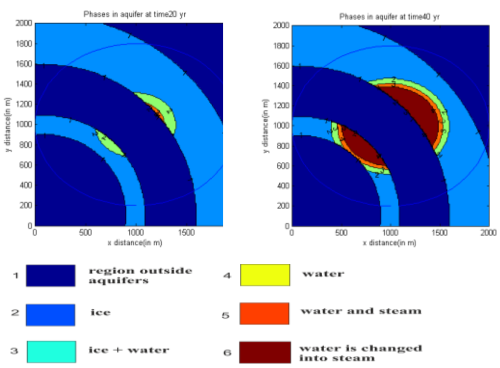

Fig. 3 Phases of water in aquifers heated by magma (ellipse given by blue line is a position of the magma intrusion), 20 and 40 yr after intrusion.

We used constant c, ρ, k and nonlinear Q [7]. The domain is: 2×2×0.4 km. The boundary conditions are: T_s = -63°C on the surface, the heat flux 0.019 W m^{-2} at the lower limit, a zero heat flux on the side walls. We set up two arc-shaped aquifers - Fig. 3, 8 m thick at depth range of 12-20 m. The water takes up 20% of the volume and the rest is rock. The boiling temperature is T_b=10°C. The intrusion is an ellipsoid with semi-axes: 1, 0.5, 0.1 km along x, y, z axes, respectively. Its center of is in (1, 1, 0.25) km.

Fig. 3 shows the effects of heating. Note that the heating effect is rather limited. It is difficult to attribute an igneous heat source to each of cone chain. Therefore we suggest some role of clathrates as volatile and heat transport by advection.

Formation of cones chains; Partial (~13%) outgassing is possible without additional heating. However, full outgassing requires additional heating. Therefore we consider two coexisting factors required for cones formation: (1) the presence of water (or other volatiles) in the regolith (aquifer) and (2) some additional heating. The formation of a chain of cones is possible in two situations:

(a) above a linear structure containing water and areal heating. Outcrops of aquifers could serve as linear sources of volatiles. For chains (1)-(5) we suggest that they are formed above such outcrops.

(b) above a linear source of magmatic heat and the areal aquifer. A dike or a system of fissures connecting upper and lower aquifers could serve as linear source of heat

Formation of subparallel chains; Linear, subparallel structures are found in nature, e.g., dikes [8], the terminal moraines [9], some outcrops of geological strata. The last option seems be best for our chains (1-5 in Fig. 2).

Conclusions and future plans;

1) Considered cones could be a result of outgassing of regolith due to pressure drop. Additional heating can lead to total outgassing and explosive formation of cones.

2) Subparallel chains of cones were formed along the outcrops of volatile-rich sediments. This mechanism seems to be most probable for chains 1–5 in the considered region. Non-subparallel chains 7 and 8 in Fig. 2 are probable chains of rootless cones.

3) Numerical modeling indicates that magma intrusions may not be enough for completely degassing some aquifers.

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